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CONTENTS

 [III - ASIA - 111]

PLANS FOR SATELLITE RESEARCH, DEVELOPMENT DISCLOSED

Earth Resources Satellite I

Tokyo KEISOKU TO SEIGYO in Japanese Vol 21, No 2, Feb 82 pp 14-19

[Article by Kazuo Matsumoto, National Space Development Agency; received by journal 12 November 1981]

[Text] 1. Introduction

The launching of the American global observation satellite ERTS (Earth Resources Satellite, later LANDSAT-1) in 1972 was the event which opened the eyes of the world to the great value of this remote sensing technique in the areas of resource searches; agricultural, forestry, and fishing surveys; environmental surveys; disaster prevention; and shoreline observations.

This capability was demonstrated by the performance of the American project CLACIE (Large Area Crop Inventory Experiment), when it predicted wheat crops with a high degree of precision, and by the effectiveness of LANDSAT in oil and mineral prospecting, which won the admiration of the major oil companies as well as the rest of the world's prospecting companies.

In this manner, the development and utilization of the earth resources satellite as an effective means of controlling finite global resources, such as agricultural and forestry resources, mineral and energy resources, and marine products resources, are receiving increasing attention not only in the United States but in all the leading countries, including the European sector, and plans for earth resources satellites are being promoted (see Fig 1).

In Japan, the Landsat ground station was established and equipped at the Earth Observation Center of the Space Development Work Group in January 1979. Data acquisition through direct reception, treatment, and distribution is being conducted, and research and development of data utilization and analysis technology are getting under way.

At the same time, development of Japan's first earth observation satellite, the Marine Observation Satellite No 1 (MOS-1) is being promoted; its objectives are to establish basic technology for the earth observation satellite and to conduct experimental observations. It is expected to serve as one

Name of satellite	Purpose	Equipment carried	Country involved	Projected launch date
Landsat-D	Collecting global surface data	--Thematic Mapper (TM) --Multispectral Scanner (MSS)	United States	September 1982
SPOT	Collecting global surface data	--High Resolution Visible (HRV)	France	1984
ERS-1*	Ocean observation	--Active Microwave Instrumentation (AMI) (Imaging mode (SAR) Wave mode Wind mode) --Radar Altimeter (RA)	ESA**	1987

*ESA Remote Sensing Satellite
**European Space Agency

Figure 1. Plans for Worldwide Earth Resource Satellites

arm of the world's global observation network at the start of the 10-year period beginning in 1985.

In the midst of this situation, the fact that plans for the Earth Resources Satellite No 1 (hereafter abbreviated "ERS-1"), which will represent the practicalization of earth resource satellites for the prospecting of resources among a number of application areas, are taking concrete form as the result of cooperative efforts between related ministries and agencies is of great significance to Japan, which must depend on overseas sources for a large portion of its energy and food.

This paper will present for the reader's reference an introduction to the present situation of the ERS-1 plan, which is presently under study.

2. ERS-1 Plan

2.1 Purpose of Development

ERS-1 is expected to contribute to Japan's resource and energy policy, land utilization policy, agricultural policy, fishing policy, environmental policy, disaster countermeasures policy, and economic water area observation, and will serve as a satellite to collect information over a wide area not only in Japan but over the entire earth. It is expected to start operation at about the start of the 10-year period beginning in 1985.

A special aspect of the development of this satellite is the premise that it will carry on board a synthetic aperture radar, which is a high-resolution, all-weather observation sensor. Development of this equipment, together with the development of a high-resolution, visible-near infrared radiometer to be carried by Marine Observation Satellite No 1 and the satellite main body to carry the observation sensor, is being promoted, but all this will require high-level measurement technology, information treatment technology, and control technology that will have to be collected and combined. In addition, nationwide technology has to be mobilized to promote the development.

2.2 Observation Equipment

The equipment for conducting the prospecting for resources, the land surveys, and the agricultural, forestry, fishery, environmental safety, disaster prevention, and coastal observations presently planned to be carried out aboard ERS-1 include a synthetic aperture radar and a visible infrared radiometer, whose specifications are given in Table 1. These will be briefly described along with a discussion of the technological subjects below.

Table 1. Outline of Equipment Carried on ERS-1 (Targeted)

(1) ミッション機器名称	(2) 原理	(3) 観測対象	(4) 想定性能
(5) 合成開口レーダ	比較的小さなアンテナで得られるマイクロ波の反射信号を蓄積、処理して等価的に大きな開口アンテナと同一の高分解能を実現するサイドルッキング映像レーダである。この合成開口レーダは、能動型マイクロ波センサの1つであり、全天候、昼夜区別なく観測できる長所をもつ。 (6)	地形の起伏 地質構造(地下資源) 海氷分布 波浪情報 (7)	周波数 Lバンド 分解能 25m×25m オフナディア角 約33度 (8)
(9) 可視近赤外放射計	主として地球面からの可視近赤外域での太陽光反射量を各波長別に高分解能で測定し、地表面の種々の情報を含む映像情報を得る。 (10)	地形地質分布(地下資源) 植物生育分布、活力度 土地利用状況 水質 災害状況 (11)	波長帯 分解能 0.45~0.52 25m 0.52~0.60 25m 0.63~0.69 25m 0.76~0.90 25m (12)
(13) 記録装置	地上局からの衛星不可視域における観測データを記録し、衛星可視時間内に再生する。広帯域のディジタルテープレコーダである。 (14)		記録速度 60 Mbps 記録時間 約20分 再生速度 60 Mbps (15)
(16) ミッション送信機	合成開口レーダのデータ、可視近赤外放射計のデータ、記録計の再生データ、衛星基本機器のデータなどの多重化、変調電力増幅を行い、送信アンテナを経由して地上にデータを伝送する。 (17)		周波数 8025~8400 MHz (2波) 送信データレート 60 Mbps (18)

Key:
1. Name of mission equipment
2. Principle
3. Observational objective
4. Expected performance
5. Synthetic aperture radar
6. This is a side-looking reflex radar which accumulates and processes microwave-reflected signals obtained with a comparatively small antenna and displays resolution equal to a large, open-aperture antenna. This synthetic aperture radar is an active-type microwave sensor and has the feature of making observations regardless of weather or time of day.
7. Terrain projections, geologic structure (underground resources), ocean ice distribution, wave information

[Key continued on following page]

8. Frequency: L band, Resolution: 25 m x 25 m, Offnadia angle
9. Visible-near infrared radiometer
10. Measures reflected visible- and near-infrared solar radiation from the earth surface at high resolution by different wavelengths to obtain information relative to the earth surface through the reflections
11. Terrain geological distribution (underground resources), flora distribution and activity, land utilization situation, water resources, disaster situation
12. Wavelength band, resolution
13. Recording equipment
14. Records measurement data for the region invisible to the satellite from the ground office and regenerates them when the satellite is visible. It is a wide-band region digital tape recorder
15. Recording speed: 60 Mbps, Recording time: about 20 minutes, Regenerating speed: 60 Mbps
16. Mission transmitter
17. Synthetic aperture radar data, visible-near infrared radiometer data, regenerated data from recorder, and basic data on satellite performance are combined and subjected to modulated power amplification, and then transmitted to the ground via the transmission antenna.
18. Frequency: 8025-8400 MHz (2 waves), Transmitting data rate: 60 Mbps

(1) Synthetic Aperture Radar

The Synthetic Aperture Radar (hereafter abbreviated "SAR") synthesizes and processes reflected microwave signals collected by a comparatively small antenna and provides the same high resolution as an antenna with equivalently large aperture, first carried aloft on the American Seasat (Fig 2).

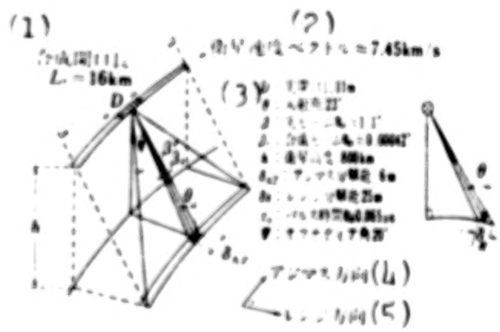

Figure 2. Principle of Synthetic Aperture Radar
(Example of Seasat)

[Key on following page]

Key:

1. Synthetic aperture length L_s = 16 km
2. Satellite velocity vector = 7.45 km/s
3. D: actual aperture length = 11 m, θ: incident angle = 23°,
   β: actual beam width = 1.1°, β_s: Synthetic beam width = 0.00042°,
   h: satellite altitude = 800 km, δ_{AZ}: azimuth resolution = 6 m,
   δ_R: range resolution = 25 m, τ_s: pulse time amplitude = 0.065 μs,
   ψ: Offnadia angle = 20°
4. Antenna direction
5. Range direction

Unlike the optical sensors of the past, which used solar ray reflections, the SAR self-radiates the energy necessary for detection; its wavelength range is more than four orders of magnitude greater than the visible-infrared range; it is essentially transparent to atmospheric water droplets (cloud and rain); and the observation time can be selected to be independent of the sun's altitude because it is an all-weather sensor.

The general outline of the SAR, which is presently undergoing test fabrication for use on ESR-1, is shown in Fig 3. This sensor is based on various complex parameters--which will be described below--for which studies are being conducted according to progress in research related to the test fabrication.

Various possibilities can be considered for the frequency and incident angle according to the application at hand, but the lack of actually measured data in Japan has made difficult the establishment of specific requirement conditions for reflection properties (back-scattering coefficient--the coefficient which gives the magnitude of reflection when electromagnetic waves are irradiated on a target--and property values correlation), and so the practice at the present time is complete dependence on the literature. In such a situation, restrictions established by hardware production, transmission power, antenna precision, and weight have led to the specifications of the use of the L band and an Offnadia angle (the inclination of the antenna beam to a direction directly downward (see Fig 2)) of about 33°, which are of the same level as those specified for Seasat. In view of the research under way to improve picture quality, and the developments in high-output semiconductors, LSI, and antenna elements, future development of the SAR using larger Offnadia angles and C and X bands is considered possible.

Range directional resolution and azimuth resolution, which comprise the resolution of synthetic aperture radar, are realized through pulse compression technology and synthetic aperture processing, and research and development on related surface elastic wave element and high-stability oscillator type electronic equipment, open antenna with good planar properties, and data treatment capabilities are thought to be important subjects for the future.

There is a factor termed ambiguity, which is a phenomenon in which a false signal from the nonobserved region is mixed in with the true signal where the picture quality of the synthetic aperture radar is concerned; observational

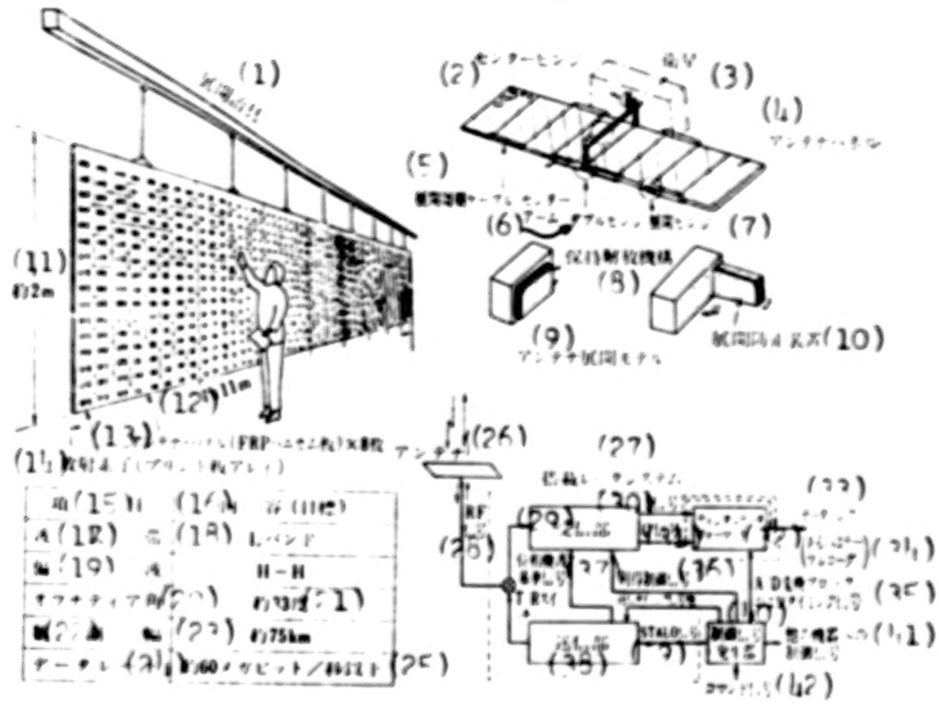

Figure 3. Diagram of Synthetic Aperture Radar

Key:

1. Opening jig
2. Center hinge
3. Satellite
4. Antenna panel
5. Opening period cable
6. Double hinge
7. Opening hinge
8. Center arm retention-release mechanism
9. Antenna opening model
10. Opening prevention device
11. About 2 m
12. About 11 m
13. Antenna panel (FRP honeycomb plates) x 8
14. Radiation element (print plate alley)
15. Item
16. Contents (targeted)
17. Wavelength band
18. L band
19. Polarized wave
20. Offnadia angle
21. About 33 m
22. Observation amplitude
23. About 23 m
24. Data rate
25. About 60 megabits/sec or less
26. Antenna
27. Radar system carried
28. RF signal
29. Receiver section
30. I signal
31. Q signal
32. Digital data format
33. Data link
34. (or a tape recorder)
35. A/D conversion block and timing signal
36. Gain-control signal
37. Phase-detection standard signal
38. Transmission section
39. STALO signal
40. Control signal generation section
41. Control signal to other equipment
42. Command signal

amplitude and resolution have to be improved, while control conditions have to be established for the radar pulse repeat frequency and radar antenna aperture length in order to prevent this ambiguity. Consequently, it becomes very important, in designing a system, to establish to just what degree the ambiguity that mixes in with the frequency and time treatment region in the manner depicted in Fig 4 should be suppressed.

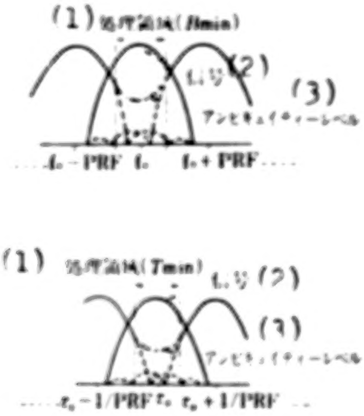

Figure 4. Ambiguity of Radar Image

Key:
1. Treatment region
2. Signal
3. Ambiguity level

In addition to the above, the shape has to be designed to enable enclosure within the fairing when this SAR is to be loaded on a satellite and launched with the H-I rocket (2-stage), whose development is presently under way by the Space Development Work Group.

This is why it is thought desirable to obtain the cooperation of related organs engaged in research on the relationships between electromagnetic properties and physical properties and research on test production experiments and data treatment presently under way under domestic technology, in order to assure technological materialization.

(2) Visible-Near Infrared Radiometer

The visible-near infrared radiometer measures with high resolution the visible and near infrared region solar radiation reflected from the earth's surface according to different wavelengths. It is an observation instrument for obtaining pictures of the earth and is capable of providing various information (Fig 5). This type of observational equipment is being developed for use with MOS-1, but actual use on ERS-1 is targeted, and higher level technology (high resolution, light weight) is being aimed at.

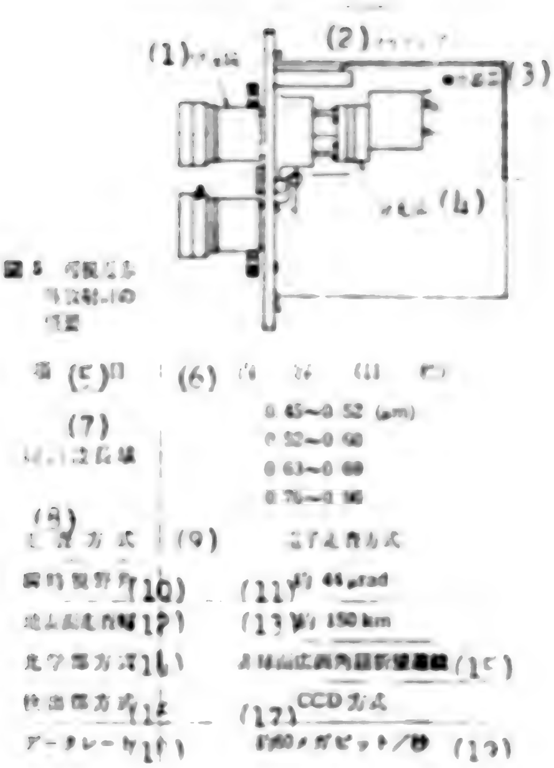

Figure 5. Features of Visible-Near Infrared Radiometer

Key:

1. Telescope	11. About 44 μrad
2. Preamp	12. Earth surface scanning amplitude
3. Detector section	13. About 150 km
4. Spectral section	14. Optical section
5. Item	15. Nonspherical wide picture angle refraction telescope
6. Contents (targeted)	16. Detector section
7. Observed wavelength region	17. CCD type
8. Scanning method	18. Data rate
9. Electronic scanning method	19. About 60 megabit/sec
10. Instantaneous visible angle	

The visible-near infrared radiometer for ESR-1 use will employ a charge transport device (charge coupled device, CCD) type of electron scanning mode, just as in MOS-1, but the spherical refraction telescope developed for MOS-1 makes it difficult to cope with weight and apherical surface strains for wide picture angles, such as at observation amplitude of about 150 km (altitude about 570 km), and the nonspherical refraction type is considered superior for future applications. The technology for finishing, polishing, and measuring this nonspherical lens is a subject for future research which will require a high level of domestic technology.

On the other hand, where CCD is concerned, the unit developed for MOS-1 will be used, and the relationships between adjustment of the focal plane, attitude

control, and data treatment will probably employ a mode which deploys the units within the same plane as shown in Fig 6 or combine the prism or fiber optics with CCD; technological comparisons between the two will probably be future subjects for study.

Other equipment to be carried aboard the satellite besides the abovementioned synthetic aperture radar and visible-near infrared radiometer are data recording equipment (data recorder) to record and reproduce the data from the above instruments and data transmitters to transmit the data to Earth. The former has to be at least a 60 Mbps digital recorder/regenerator; development in Japan of a high-speed data recorder for use in space is considered a very difficult problem at the present time.

Figure 6. Method of Image-Forming to Detector

Key:

1. Method of deploying into the same plane
2. Method using half-prism
3. Method using fiber optics
4. Image-forming lens
5. Image-forming lens

2.3 Satellite Main Body

The satellite main body which will carry the observation equipment introduced in the preceding section will have the shape and general specifications given in Fig 7. Studies will be carried out in the future regarding the aboard observation equipment, reducing the weight of a satellite and the orbit entry to make possible the launching of this satellite with the H-I rocket (2-stage).

Because the altitude of 570 km is a rather low orbit with correspondingly large air resistance which, together with the large area of both the synthetic aperture radar and solar battery panels, is expected to cause the external turbulence to be about 10 times that of MOS-1. In order to cope with this situation, the use of a zero momentum mode triaxial attitude control system is envisioned, so as to enable adequate orbital and attitude control. It is believed that analysis on dynamic response of pliable structures and the effect on attitude of gas jet fumes for attitude control will be important subjects for future research and development.

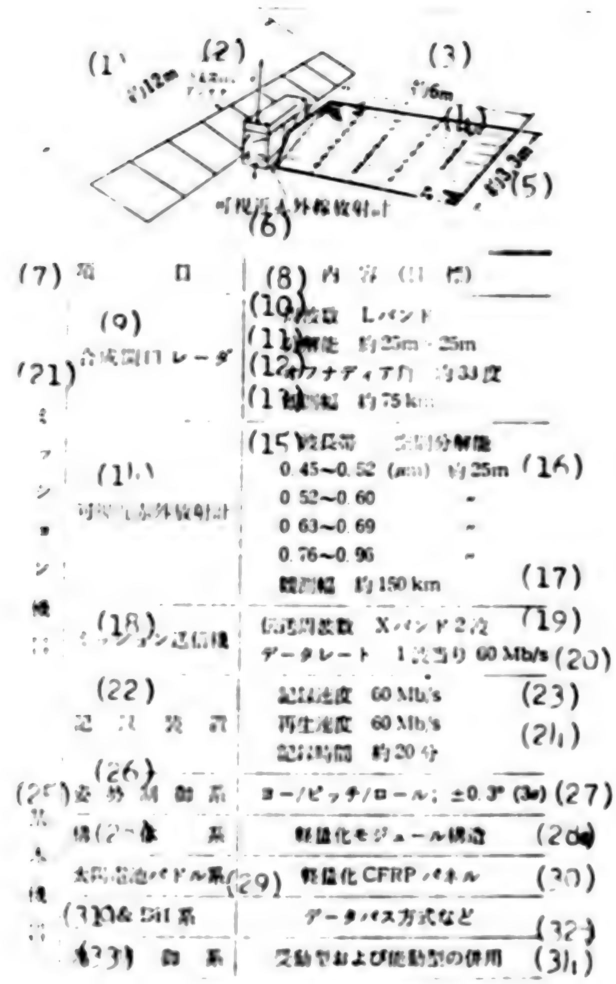

Figure 7. Specifications for ERS-1

Key:

1. About 12 m
2. SAR antenna
3. About 6 m
4. Solar battery paddle
5. About 3.3 m
6. Visible-near infrared radiometer
7. Item
8. Contents (targeted)
9. Synthetic aperture radar
10. Frequency: L band
11. Resolution: about 25 m x 25 m
12. Offnadia angle: about 33°
13. Observation amplitude: about 150 km
14. Visible near infrared radiometer
15. Wavelength band, space resolution
16. About 25 m
17. Observation amplitude: about 150 km
18. Mission transmitter
19. Transmission frequency: X band, 2 waves
20. Data rate 60 Mbps/wave
21. Mission equipment
22. Recording equipment
23. Recording speed: 60 Mb/s
24. Reproducing speed: 60 Mb/s, recording time: about 20 min

[Key continued on following page]

25. Base equipment
26. Attitude control system
27. Yaw/pitch/roll: $\pm$ 0.3° (3σ)
28. Structural system
28a. Lightweight modular structure
29. Solar battery paddle system
30. Lightweight CFRP panel
31. C and DH system
32. Data bus mode, etc.
33. Thermal control system
34. Joint use of passive type and active type

Where the load weight ratio of observational equipment was 20 percent in the past, that of ERS-1 is about 30 percent, so a structural system of lightweight and ready integration capability should be subject to research and development.

On the other hand, considerable electric power is required for the SAR and other equipment, so there will be a need for research on high-power solar battery panels, on making concentrated control of data treatment and commands within the satellite, and on developing a data bus mode that will facilitate integration. Thus, many problems will have to be resolved to pave the way for future real satellite development.

2.4 Possibility of Utilization

Since ERS-1 is a satellite which will carry aboard various observational equipment, as described above, in order to acquire information over a wide area of the entire world, it may be thought that utilization as displayed in Table 2 will be possible, but there will be a need here for advances in utilization demonstration research in the various areas, demonstrational experiments in global resource satellite observation systems through the cooperation of organs related to development and utilization, and accumulation of data necessary for practicalization in order to advance practical applications in the various areas of utilization.

Once the usefulness of the satellite is recognized as the result of the steps outlined above, the next important subject will be the time span for acquiring data, coordinating efforts and supplementing functions with satellites of other countries; the launching of several satellites of the same type into orbit will become necessary in order to resolve this problem.

Table 2. Areas of Potential Utilization by
Earth Resources Satellite No 1 (ERS-1)

1 利用分野	2 利用目的	3 使用センサ
7 資源探査	・地形構造の解析と地下資源賦存状況調査 8 ・地形図作成 9 ・地質構造の解析と地下資源賦存状況調査 10 ・地質図作成 11	SAR, VNIR
17 国土調査	・土地被覆図 18 ・土地利用現況および土地利用変化状況把握 19 20	SAR, VNIR
27 農業資源管理	・土地被覆分類および生産力評価 28 ・農林地域計画基本図 29 ・収穫量予測 30	SAR, VNIR
36 林業資源管理	・木材資源量 37 ・森林災害 38 ・土地利用状況および変化状況 39	SAR, VNIR
42 水産業	・漁場の探査 43 ・流氷の探査 44 ・赤潮の検知 45 ・海象情報 46 ・海面汚濁の検知 47	VNIR SAR, VNIR VNIR VNIR, SAR VNIR

4 利用分野	5 利用目的	6 使用センサ
12 環境監視	・自然環境変化監視 13 ・居住環境変化監視 14 ・陸水域の水質汚染 15 ・沿岸海域における水質汚染監視 16	SAR, VNIR VNIR
21 防災	・地震防災 22 ・火山防災 23 ・地すべり 24 ・洪水 25 ・雪害 26	SAR, VNIR VNIR SAR, VNIR
31 沿岸域監視	・海岸地域監視 32 ・沿岸水域監視 33	SAR, VNIR
34 その他	・水資源管理 35	SAR, VNIR

SAR：合成開口レーダ 40
VNIR：可視近赤外放射計 41

Key:

1. Utilization area
2. Utilization objective
3. Sensor used
4. Utilization area
5. Utilization objective
6. Sensor used
7. Search for resources
8. Topographic analysis and survey on underground resources
9. Making of topographic maps
10. Analysis of geologic structure and survey of underground resources
11. Making of geologic maps
12. Environmental observations
13. Observations of changes in natural environment
14. Observations on changes in living environment
15. Observations on water pollution on land water areas
16. Observations on water pollution in coastal areas
17. Country survey
18. Map of land under observation

19, 20. To view utilization status and follow changes in land utilization

21. Disaster prevention
22. Earthquake disaster prevention
23. Volcanic disaster prevention
24. Landslides
25. Flooding
26. Snow damage
27. Agricultural and forestry resources management
28. Classification of land under observation and evaluation of productivity
29. Basic map for agricultural and forestry regional plans
30. Yield predictions
31. Observations of coastal regions
32. Observations of seacoast areas
33. Observations of adjoining seas
34. Other areas
35. Marine resources management
36. Agricultural and forestry resources management
37. Magnitude of forest resources
38. Forestfire damage
39. Land utilization status and changes in utilization
40. SAR: Synthetic aperture radar
41. VNIR: Visible-near infrared radiometer
42. Marine industries
43. Search for fishing sites
44. Search for icebergs
45. Detection of red tides
46. Marine weather information
47. Detection of marine pollution

Through the development and operation of a practical and experimental earth resources satellite system in the manner depicted in Fig 8, various long-term benefits to our country may be anticipated, including the development of space-related industries, technology spinoff effects, international cooperation, and independent information collecting capability.

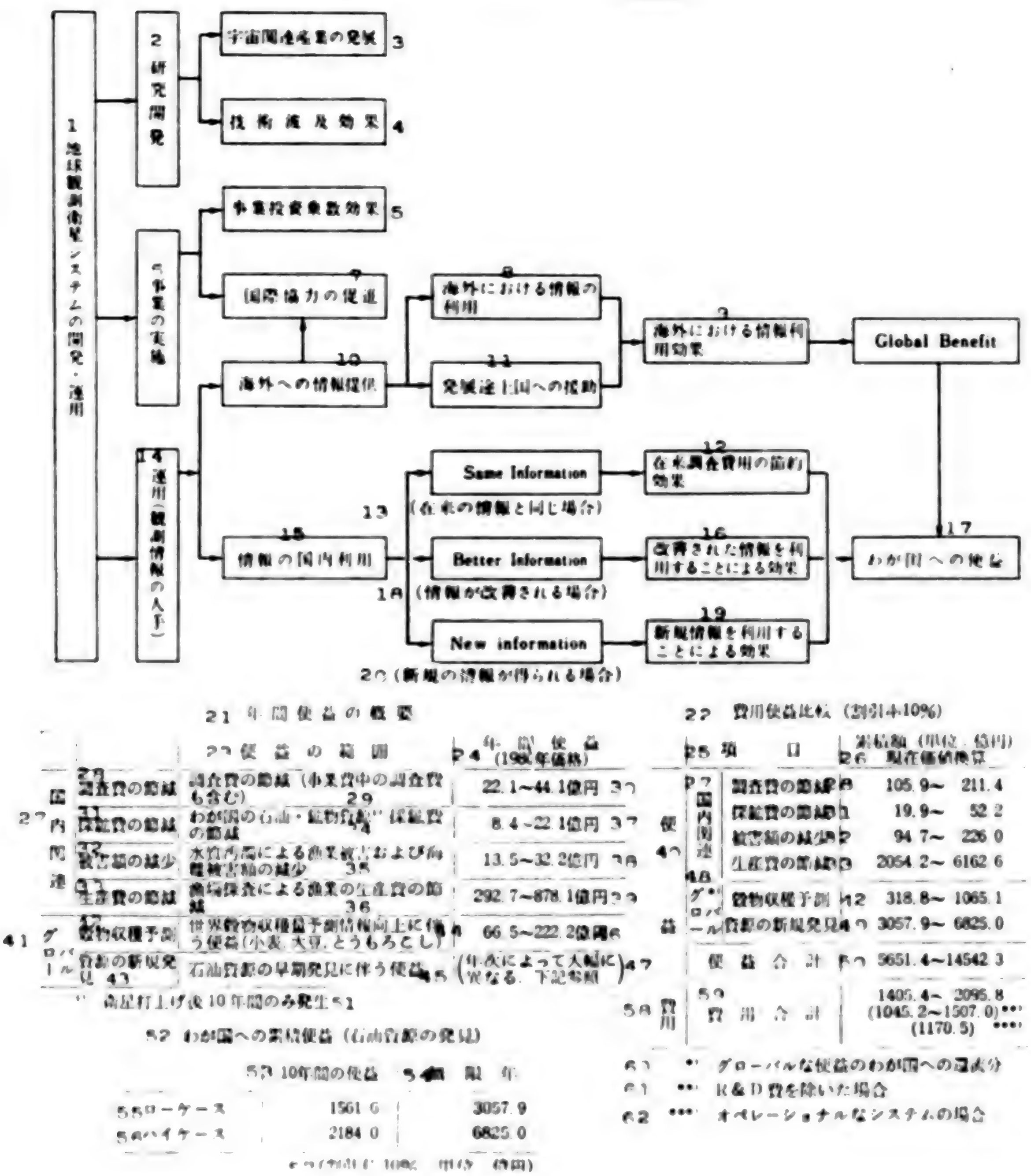

Figure 8. Benefits From Earth Resource Satellite

[Key on following page]

Key:

1. Development and operation of earth observation satellite system
2. Research and development
3. Development of space-related industries
4. Technology spinoff effect
5. Industry financial synergistic effect
6. Execution of function
7. Promotion of international cooperation
8. Utilization of information overseas
9. Information utilization effect overseas
10. Furnishing information overseas
11. Assistance to developing countries
12. Saving effect on present survey costs
13. (When same information as before is used)
14. Operation (acquisition of observation information)
15. Domestic use of information
16. Effect of using improved information
17. Benefits to our country
18. (When information is improved)
19. Effect of using new information
20. (When new information can be obtained)
21. Outline of yearly benefits
22. Costs and benefits comparison (10 percent discount rate)
23. Range in benefits
24. Yearly benefits (1980 price)
25. Item
26. Cumulative sum (unit: 100 million yen) calculated on present price level
27. Domestically related
28. Saving in survey cost
29. Saving in survey cost (includes survey costs within the operational costs)
30. 2.21-4.41 billion yen
31. Saving in prospecting costs
32. Reduction in disaster damage
33. Reduction in production costs
34. Reduction in this country's oil and mineral prospecting costs
35. Reduction in fisheries damage and sea disaster damages
36. Conservation of production costs of fishery industry through fishing ground search
37. 0.84-4.41 billion yen
38. 1.35-3.22 billion yen
39. 29.27-87.81 billion yen
40. Benefits
41. Global
42. Prediction of grain yields
43. Discovery of new resources
44. Benefits derived from improved information for predicting world's grain yields (wheat, soybeans, corn)
45. Benefits from early discovery of oil resources
46. 6.65-22.22 billion yen
47. Varies greatly with year. See notes below
48. Global
49. New resource discoveries
50. Total benefits
51. Generated in only the 10 years after satellite launch
52. Cumulative benefits to Japan (discovery of oil resources)
53. Benefits over 10 years
54. Unlimited time
55. Low case
56. High case
57. Discount rate 10 percent, unit 100 million yen)
58. Cost
59. Total costs
60. *: returns to Japan from global benefits
61. **: with R and D costs removed
62. ***: case of operational system

3. Summary

The studies being conducted presently, the outline of the overall plan, and the problems encountered in the development of the ERS-1 were introduced.

This plan is in no way inferior, even when judged on an international basis, and its development through a concentration of domestic technology is believed capable of providing great results.

In conclusion, we are expecting the cooperation of utilization organs, related national and public research organs, universities, and private parties for the coming research and development and the promotion of development, and we are asking for the support and cooperation of all related parties.

Postscript: Measurements and Control in Space Development

Space presently represents one of man's frontiers alongside the oceans. Ever since the distant past, man has looked at the sun, moon, and stars with various ideas in mind. Nearly a quarter of a century has elapsed since the opening of the curtain on the space era with the launching of Sputnik in 1957. There are a number of manmade satellites circling the earth which are being used in meteorological surveys, communications, and the search for resources, while search craft are exploring interplanetary space and new discoveries are being made one after another. However, these spectacular results of space development cannot be thought of without measurement and control technology. It would not be amiss to call space technology the personification of measurement and control technology. The difference between ground measurement and control technology is that remote measurement and remote control are the essential ingredients, and there are extremely severe demands on reliability and environment-resistant properties. Space development has come forth with various new technologies along the lines of observation equipment, remote sensing, and remote communication. Space development is an area for problem proposals on the part of researchers and technologists, and it is constantly applying stimuli to create new technology as well as theory. The Kelly maximum steep descent method has been proposed to solve the optimization problem of the reentry orbit of spaceships. The Carmen filter was used successfully as a navigational filter in the Apollo Plan and then was applied to the solution of the LQG problem for the launching of the Saturn 5 rocket. The maximum-value principle applied to the Mariner was used in the orbital calculations for the exploration of Mars and the Viking Project, and the practical applications of control theory are well known. There are any number of examples in which control theory is being applied in the area of simulation and feasibility studies. The father of rockets, Zuiolkofsky, said: "The earth is mankind's cradle. We must not dawdle forever in it." We pray that every SICE member embraces the dreams and hope of space development.

(Toru Shiura, National Aerospace Laboratory)

PLANET A Project

Tokyo KEISOKU TO SEIGYO in Japanese Vol 21, No 2, Feb 82 pp 20-24

[Article by Hiroyoshi Matsuo, Space Science Laboratory; received 12 November 1981]

[Text] 1. Introduction

Halley's Comet will make its return orbit in 1986 after 76 years. This will be the occasion for the launching of an interplanetary exploration craft which will make observations close to this comet according to a project being promoted with the Space Science Laboratory as mainstay. This will be Japan's first interplanetary flight, so it will be called PLANET-A, and the general outline of this project will be described below.

The planets and comets of the solar system are believed to have been formed from the same type of material, but where the planets have changed in nature from their initial state during their long developmental stage, comets have spent most of their existence outside the solar system and have not been exposed to the fierce effects of the sun. At the same time, their nuclear sections are small and mostly of the order of a few kilometers, so that the changes in internal structure caused by gravitational effects are small, and they are thought to have retained their original state rather faithfully. As a comet makes its approach to the sun, fresh layers of the surface are constantly exposed. Unless they are very large, comets with short cycles lose nearly all of their volatile components through repeated passes close to the sun, so that they assume inactive states. On the other hand, the orbits of those comets that belong to the long-cycle group, such as those which have made but one pass in the course of man's history, cannot be predicted with any great accuracy, and these [comets] cannot be observed by the spaceship which will be described below. In this respect, the orbit of Halley's Comet is known rather precisely, and it is a comet which still retains a good fraction of its volatile components; this coming reappearance is an excellent opportunity to study this comet.

2. Observation Plans of the Different Countries

At the present time, ESA (the European Space Agency) and the Soviet Union are the parties other than Japan which are planning to launch probe ships to study Halley's Comet. ESA had been planning a joint effort with NASA (the American space agency), but NASA did not follow up its plans, as will be discussed later, so ESA changed its plans and decided to make an independent launch, using an Ariens rocket. This venture is called Giotto, and the spaceship will use a spin-stabilized camera for picture-taking and mass analysis capability with emphasis on on-site measurements. The plan is to cruise to the proximity of the nucleus of the comet (about 500 km). The launch will take place in the summer of 1985. The Soviets initially had planned a joint effort with the French in which an orbiter and an observation balloon would be sent to Venus, but the plan was altered and the orbiter part was discontinued. The new plan involves dropping a probe on Venus that would then be

directed toward Halley's Comet. This plan, called Venera-Halley, is being developed under the title Intercosmos and being promoted with the participation of both East and West European scientists. This probe ship will use a triaxial control mode, will engage in a roughly equal ratio of remote and direct measurements, and will approach to within 10,000 km of the nucleus. Two probe ships will be launched at the end of 1984 and be directed toward Halley's Comet from Venus in June 1985. The rendezvous with Halley's Comet will take place in the first part of March 1986 for both Giotto and Venera-Halley because of reasons to be discussed later.

NASA had been planning an ambitious program using a probe ship powered by an ion engine (a so-called advanced propulsion system, using solar light as the energy source, in which the propulsive force derived would be small but of large thrust per unit propulsive mass expenditure, thereby affording a small expenditure of propulsion material) to fly past Halley's Comet and go to the Tempel 2 Comet. The ion engine development did not materialize, however, and the plan was discarded. NASA then changed its plans and opted for a program whereby a probe ship would be launched from a space shuttle simply to observe Halley's Comet. This plan also suffered from budgetary inadequacies, and the present situation unfortunately is that NASA has no special plans of its own. In its place, NASA proposes to organize observations on an international scale from the ground and from orbiting satellites. This plan has been dubbed IHW (International Halley Watch), and NASA will be its principal instigator.

It was only natural that a movement was begun to exchange information being gathered by the plans which each country was independently promoting and to adjust the plans to the extent possible in order to enable greater efficiency in the observations. The first conference of the four organizations--NASA, the Soviet Science Academy, ESA, and ISAS (Space Science Laboratory) of Japan --was held at Padua, Italy, in September 1981. A working group was formed, and consensus has been reached on promoting cooperative efforts.

3. Observation Plan for PLANET-A

The nucleus of Halley's Comet is an aggregate of primordial material dust with a diameter of about 10 km and contains large quantitites of frozen volatile components such as H_2O, HCN, and CH_3CN, so that it has sometimes been called "a dirty snowman." As the comet nears the sun, (1-2 AU), it is heated and the surface ice particles begin to vaporize, as a result of which the resulting gas and dust particles form a frame around the nucleus. The fine dust particles are further tossed about by solar radiation pressure and form a tail about 0.3 AU (45 million km) long in the direction away from the sun. The vaporized gases dissociate upon irradiation by ultraviolet radiation from the sun and generate large quantities of hydrogen atoms. The velocity of these hydrogen atoms differs with the production process; the velocities obtained in measurements made in the past are very tentative, so the mechanisms responsible for the formation of these hydrogen atoms are still not clearly understood. These hydrogen atoms are resonantly scattered in selective manner by the Lyman α lines of the solar radiation. Observation of the hydrogen frame through the Lyman lines should enable observations on the growth and decay processes of the hydrogen frame.

Plans are under way to develop the technology for snap photography of aurora Lyman lines which had been successfully demonstrated by the scientific satellite "Kyokko" and place it on PLANET-A in order to observe the growth-decay process of Halley's Comet over a long timespan. It was expected that a decisive answer to the above problem would be forthcoming from this approach. PLANET-A will also carry a charge particle energy spectrometer to observe the energy distribution of the solar wind particles and thereby establish the nature of the solar wind. At the same time, there are plans to launch prior to PLANET-A an experimental probe ship called MS-T5 which will be used to conduct engineering experiments on rocket launchings and extremely remote communication, but it will also carry proton-density measurement devices for protons in the solar wind, a plasma-wave measurement device to be used on solar wind plasma, and magnetic field measurement devices. By placing the MS-T5 nearby when PLANET-A approaches Halley's Comet, important data relative to the solar wind distribution should be forthcoming from the simultaneous observations.

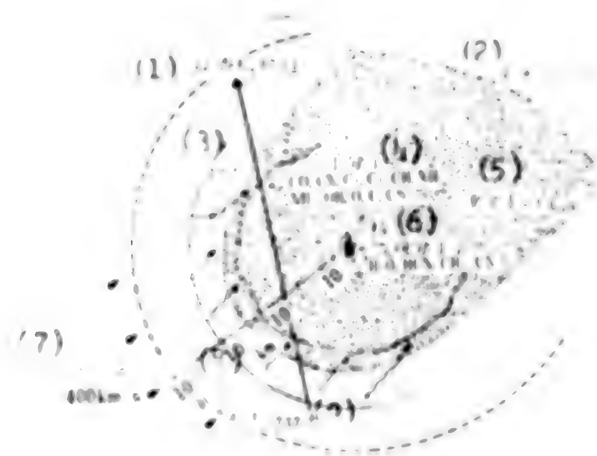

Figure 1. Model of Halley's Comet [2]

Key:

1. Probe ship orbit
2. Ion tail
3. Frame
4. Daughter molecules
5. Dust tail
6. Parent molecules
7. Solar wind
8. Distance
9. Hydrogen corona

4. Orbit of PLANET-A

The orbital details of Halley's Comet are given in Table 1. Its period is 76 years, and other items of note are the fact that the direction of its circuit is opposite to that of the earth and other planets, and the angle of its orbital plane is 18° with the ecliptic plane. This is why the Halley mission will be subjected to restrictions different from the other satellite missions. These include the following:

(1) The relative velocities when the probe ship and Halley rendezvous will be extremely large (about 70 km/s); the residence time near the comet will be extremely short; and protection of the probe ship from collisions with dust particles from the comet will be a major problem.

(2) The point of confluence with Halley will be limited to the two points of the ascending and descending intersections that Halley makes with the ecliptic plane. Otherwise, the orbit of the probe ship cannot help but deviate from the plane of the ecliptic, and large energy will have to be expended in the launching.

Table 1. Orbital Elements of the Halley Comet

Perihelion distance	0.5871 AU
Eccentricity	0.9673
Orbital declination	162.24 deg
Perihelion hour angle	111.85 deg
Ascending node	58.15 deg
Date of perihelion	9 Feb 1986

A factor of primary importance in selecting the orbit is the launching energy, as this relates directly to the weight of the probe ship which can be launched. The ordinate for Fig 2 is the launch date, and the results of a search for the minimum launching energy at fixed launch date to enable a synodical orbit are shown in this figure. The launching energy is given as a second power function $C_3 \equiv V_{oo}^2$ of the relative velocity V_{oo} of the probe ship with respect to Earth at the time of escape from Earth. This figure shows two groups, representing the meetings at the ascending and the descending pathways. Minimum energy is involved with a launch in the summer of 1985 for a meeting on the descending pathway during the early part of March 1986. While not shown here, an orbit is possible in which the launch date can be advanced and the probe ship can make several circuits about the sun before approaching the orbit of Halley's Comet. Because of these energy considerations, there is a need to establish more precisely the orbit of Halley's Comet. In addition, the comet will be in an activated state after it passes the perihelion, thus making it more readily observable, and all of the countries involved are planning on a rendezvous during the descending pathway. The same holds true for PLANET-A.

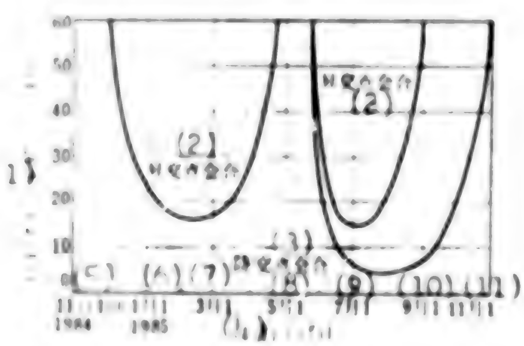

Figure 2. Launch Date and the Launching Energy for the Halley Comet Probe

[Key on following page]

Key:

1. Launching energy C_3-km^2/s^2
2. Ascending rendezvous
3. Descending rendezvous
4. Launch date
5. 1 Nov 1984
6. 1 Jan 1985
7. 1 Mar
8. 1 May
9. 1 Jul
10. 1 Sep
11. 1 Nov

The tentative orbit for PLANET-A is shown in Fig 3, and the orbital elements are listed in Tables 2 and 3. The probe ship, which has been accelerated from the earth's surface by the launching rocket to the rate shown in Table 2, is detached from the earth's gravitational field and will thereafter travel in interplanetary space. The orbital elements centered on the sun are shown in Table 3.

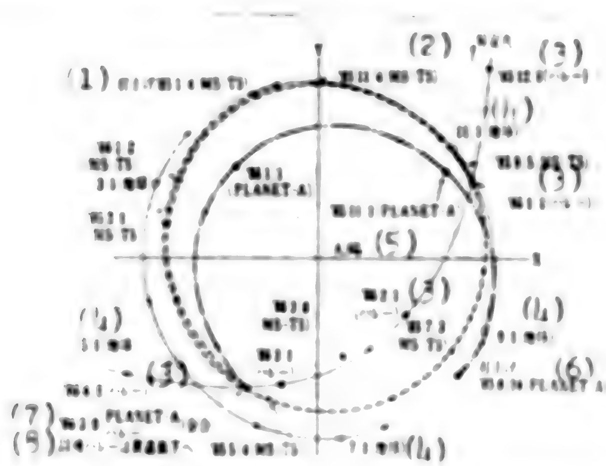

Figure 3. PLANET-A Orbit (Ecliptic Plane Projection)

Key:

1. Launch (MS-T5) 4/1/85
2. Ascending rendezvous
3. --- (Halley)
4. --- (Earth)
5. Sun
6. Launch (PLANET-A) 14/8/85
7. Rendezvous (PLANET-A and Halley) 8/3/86
8. Halley falls below ecliptic plane thereafter

MS-T5, which will be launched half a year prior to PLANET-A, will make one revolution around the sun, after which, according to this plan, it will rendezvous with PLANET-A at about the time said planet comes close to Halley. MS-T5's orbit is also shown in Fig 3. The double-line orbital section is used to demarcate the orbital section after one revolution; the actual situation is that the same orbit is followed.

Table 2. Conditions for Disengaging Orbit for PLANET-A
(1 AU = $1,496 \times 10^8$ km)

Altitude from earth's center	6,578 km
Latitude	30.91 deg (N)
Longitude	138.00 deg (E)
Velocity	11.366 km/s
Flight course angle*	2.32 deg
Flight azimuth**	94.89 deg
Launch date	14 Aug 1985

*Angle between velocity vector and horizontal plane of ground station

**Angle between velocity vector and projection of true north on horizontal plane of ground station

Table 3. Orbital Elements of PLANET-A

Semi-major axis	0.8507 AU
Eccentricity	0.1925
Orbital inclination	0.70 deg
Perihelion hour angle	147.15 deg
Ascending node	140.93 deg
Perihelion date	30 Mar 1985

5. Flight Plan and Orbital Precision

PLANET-A will be launched with an M-3S II rocket. The M-3S II will be an improvement over the present M-3S rocket used to launch the scientific satellite; it will have double the capability, and will be a three-stage rocket using solid fuel throughout. Where the PLANET-A mission is concerned, a fourth stage in the form of a kick motor is planned (Fig 4). PLANET-A, which will be shot up in a direction nearly due east from the Uchinoura station in Kagoshima Prefecture, will be accelerated into a horizontal orbit at the apogee of the second stage orbit (about 200 km) by the kick motor and the third stage and enter a disengaging orbit. This is what is referred to as a direct launch into orbit. The usual situation is to enter a globe-circling orbit (packing orbit) and then refire at some suitable place on the orbit to enter a disengaging orbit. Only the magnitude of V_{oo} was considered in the preceding section, but there is a need to consider the disengagement direction at the same time, and the use of the packing orbit mode increases the degr e of freedom, as a result of which the release from the earth's gravitational field can be in any desired direction. On the other hand, when the weight of the control equipment required to readjust the attitude in packing orbit was considered, this extra weight became a bind on the weight of the probe ship, and this is the rationale for using the direct launching mode for Planet-A. This is why the minimum V_{oo} orbit of Fig 2 is not one which can also be adopted, because of the restriction as to the direction of release.

After it leaves the field of vision, the probe ship will become visible once more from Uchinoura after about 4 hours, and this will continue for about 9 hours. This period will be exploited to make orbital designations using the 10 mϕ antenna at Uchinoura, and information necessary to program followup will be obtained through the Deep Space Office (64 mϕ antenna) presently being planned. In addition, the attitude will be changed from the state at launching to a cruising mode with the spin axis perpendicular to the plane of the ecliptic. This will be followed by careful determination of the orbit by the Deep Space Office, and the first orbital corrections will be made after 5 days to remove any errors from the orbit. If needed, a second correction may be made to improve the precision, and it is believed that orbital corrections will be limited to these two, in view of the nature of the mission. As the cruising attitude is assumed, the forward half will be engaged mainly in measuring the solar wind, while the rear half which will have a large visible angle on Halley, and will photograph Halley using vacuum ultraviolet light. During this interval, hydrazine jets will be used at 10-day intervals for attitude control in order to compensate for the disturbance to the attitude by solar radiation pressure.

Figure 4. M-3S Rocket

PLANET-A has as its primary objective the remote photography of Halley. Very precise orbital precision is not required from the standpoint of these observations, but there is need to consider precision for the establishment of engineering technology for use in future satellite flights. There are many factors related to orbital dispersion which need to be studied--particularly those with major impact--and errors of the magnitude described below are expected at the present time.

Factors associated with orbital dispersion include:

(1) Error in setting orbit of the probe ship

(2) Uncertainty in the orbit of Halley's Comet

(3) Orbital launching errors

(4) Orbital correction errors.

[All of these] come to mind, but factor (3) looms as the most probable to be reckoned with for the PLANET-A mission because of the limitations to the quantity of propellant for correction use.

(1) According to the results of the first study, the Deep Space Office (range rate 1σ = 6 cm/s) made orbital determination for 4 days after launch, and the positional error at the time of rendezvous with Halley was 1σ = 143 km.

(2) Because of the particular need to consider grav.ty-free conditions, this is a bothersome task, and the situation shown in Fig 5 arises according to reference (1). In this figure, t_m is the error in the time of closest approach between the probe ship and Halley, while X and Y are the positional errors within the plane normal to the relative velocity. Observations during 1985 will not be very effective, because Halley will not be visible but be moving toward Earth, and orbital corrections will have to be made after the latter part of 1985 if better precision is required.

(3) PLANET-A will be provided with a maximum 100 m/s velocity-correction capability because of the nature of the mission and the weight limitations. The necessary corrections for representative combinations in velocity-vector errors during launch are listed in Table 4. In these calculations, the point of arrival was taken to be at the movable end, and a rendezvous point which would enable minimum correction was reestablished. This approach is essentially insensitive to azimuthal errors, and if the velocity error generated at the time the disengaging orbit is entered is corrected after establishment of the orbit (5 days after launch), a correction roughly four times as large becomes necessary. Based on the above, it would seem that the correction capability suffers in getting to the initial targeted point. If, in the situation of case 2, the method of Table 4 were used for convenience to correct the direction, a correction of only 100 m/s could be made with respect to the necessary 162 m/s velocity, and this would create an error of about 1.3 million km in the distance of closest approach between Halley's Comet and PLANET-A.

(4) Where velocity correction is concerned, the possibility is that changes in the propulsion level of the thruster will be the main culprit responsible for error, and the magnitude of this correction cannot be established until the orbital determination--which comes later--is set. On the other hand, the error will be proportional to the degree of correction, and there is the possibility, in principle at least, that increasing the number of corrections will reduce the final positional error. For example, assume that two corrections rounds are made after 40 days in the situation of case 3 and there is

a correctional error of 3 percent per round; then the final positional error will be 6,000 km, and the second correction will be 4.5 m/s.

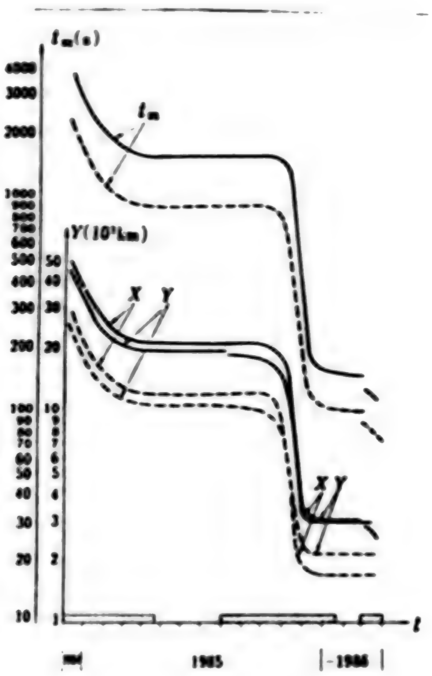

Figure 5. Positional Uncertainty of Halley

Table 4. Orbital Entry Error and Necessary Corrections

	速度誤差 (1)(m/s)	飛しょう経路角誤差 (deg) (2)	飛しょう方位角誤差 (deg) (3)	必要修正量 (4)(m/s)
(5) ケース 1	±30	0	0	128.5
ケース 2	±30	±0.5	0	161.8
ケース 2	±30	∓0.5	0	97.0
ケース 4	±30	0	±0.5	128.5
ケース 5	±30	0	∓0.5	129.8

Key:

1. Velocity error (m/s)
2. Flight path angle error (deg)
3. Flight azimuthal error (deg)
4. Necessary correction (m/s)
5. Case --

6. Structure of the Probe Ship

The total weight of PLANET-A (Fig 6) will be about 135 kg. The weight allotments for the various constituent elements are given in Table 5.

PLANET-A with orbit centered on the sun will travel (cruising mode) with its spin axis normal to the ecliptic plane in order to assure maximum communication with the earth and maximum reception of solar energy. Its attitude

stability at this time will basically be maintained by the angular momentum of the momentum wheel carried aboard, but the craft will also be provided with six jets which use hydrazine as fuel to enable corrections for external turbulences (each jet will have thrust of 300 g). The probe craft will rotate about its spin axis at low speed in a cruising mode. This rotation will be 6 rpm during solar wind observation; it would be preferable for this rotation to be stopped during observations of the comet, but it will be held at 0.2 rpm for the purpose of temperature control. The most simple means of maintaining the attitude of this spacecraft is to spin the entire craft, but there is a need to keep the camera in essentially a still position in order to photograph the comet. This was why this approach was taken, even though it entailed some weight disadvantages.

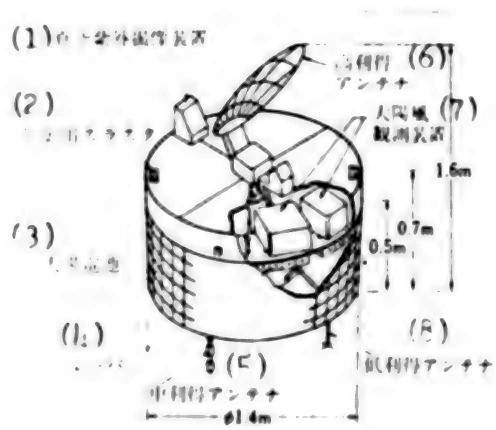

Figure 6. Shape of PLANET-A

Key:

1. Vacuum ultraviolet photographic equipment
2. Control thruster
3. Solar battery
4. Louver
5. Medium-gain antenna
6. High-gain antenna
7. Solar wind observation equipment
8. Low-gain antenna

Table 5. Weight Makeup of PLANET-A

Scientific observation equipment	10 kg
Attitude and speed-control system	31
Structural and thermal control system	26
Electric power system	22
Telemeter and command system	14
Antenna system	22
Instrumentation system	10
	135 kg

The hydrazine jets will be used for orbital corrections. As mentioned before, this corrective capability will be a maximum of 100 m/s.

Solar sensors and stellar sensors will be used to make attitude determinations. When solar light enters the slit placed in the plane of the spin axis, it will be possible from the time and direction of this entry to establish the angle between the spin axis and the sun and the phase angle of the sun about the spin axis with a precision of 0-05-1° and 0.1°, respectively. The phase angle will also be used to provide the timing for photographing the comet. Correlating the visual angle of the stellar sensor with that of a known star and combining information from the solar sensor will enable complete attitude establishment of the spacecraft.

Communication with the ground and tracking of PLANET-A will be conducted mainly with the Deep Space Office, presently in the planning stage. The spacecraft will be provided with high-, medium-, and low-gain antennae which can be used according to the distance involved and the purpose at hand. The frequency of the 5W transmission output waves will be the 2293 MHz deep-space band which has been adopted on an international basis. The high-gain antenna to be installed on this probe ship will be an 80 cm diameter offset parabola, which will be set apart from the spin of the main craft and be directed toward the earth to transmit observational data, receive commands from the earth, and measure the distance of the craft from the earth. The medium-gain antenna will be used to supplement the functions of the high-gain antenna, while the low-gain antenna will be used for transmissions over comparatively short distances, such as at the initial stage when the craft is still close to the earth. The data communication speed will be 128 bps, and a 2,048 bps mode is possible at short distances. The data recorder will have capacity of 1 Mbit, the input-output speed will be 2,048 bps, and the image of the Halley Comet (120 x 150 picsel[phonetic]) will be recorded and reduced before transmission to the earth.

The power used by this probe craft will be supplied from the roughly 2,000 solar batteries affixed to the side of the craft. The output will be 67 W when the craft is near the earth and the solar rays are normal to the plane of the batteries.

Temperature control will be maintained by thermal shielding of the probe craft surface. This shielding prevents entry of solar energy, and heat generated within will be forced out through the termal louvers under the platform and into space.

7. Summary

The PLANET-A project is proceeding, with a targeted launch date in 1985; it is operating under severe weight restrictions and many difficulties. It is hoped that success will be realized in supporting one phase of the world's observational effort to enable establishment of interplanetary flight technology, so that there can be PLANET-B and PLANET-C projects to follow.

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Marine Observation Satellite

Tokyo KEISOKU TO SEIGYO in Japanese Vol 21, No 2, Feb 82 pp 25-30

[Article by Sadahiro Ishizawa, National Space Development Agency; article received by journal 6 November 1981]

[Text] The ability to maintain constant observation over marine phenomena such as changes in ocean tides, fog, and red tides which have great impact on fishing is very important to Japan, which depends so heavily on marine resources. If it were possible to relate observational data with the search for schools of fish, the efficiency of fishing would be greatly improved, and this, together with the conservation of fuel, could result in bringing about very great advantages overall. At the same time, marine observations should make possible the prediction of long-term changes in meteorological phenomena, while constant observation of coastal areas can be effectively exploited as pollution monitoring and observation of inland water resources serve to benefit agriculture and forestry and be useful as an early-warning device in the event of water shortages.

With the above situation in mind, the development of an earth marine observation system through the use of an artificial satellite for effective utilization of earth resources and preservation of the environment has begun, and a start has been made to launch this satellite from the Tanegashima range with the N rocket in the summer of FY86.

1. Mission and Operation of Marine Observation Satellite 1

The following will be the mission of Marine Observation Satellite 1 (MOS-1):

1. Establish basic technology for earth observation satellites

2. Develop visible-near infrared radiometer, visible thermal infrared radiometer, and microwave radiometer; demonstrate their functional capabilities; and use these three instruments to make experimental observations of the entire world, concentrating on the oceans

3. Conduct basic experiments on data collection system

4. Practice technology of launching into orbit synchronous with the sun

5. Practice technology of tracking control of orbits synchronous with the sun

6. Practice technology of operating earth observation satellite.

Design and production of the satellite to be used in the fulfillment of these missions, and development of the associated ground systems, are anticipated.

Since an orbit which is retrograde to the sun's cycle is effective for observing land and sea areas, using the radiometers to be carried aboard the MOS-1, the orbit of the MOS-1 will be a retrograde orbit synchronous with the sun, with average regional solar time of 10-11 AM for the descending node, 17 days for retrograde motion, and 14 cycles per day. According to this orbit, the real-time operation of the same ground office will be roughly the same time-band each day, and there will be a return to initial orbit every 17 days. This orbit will be circular and have a period of 103 minutes, an altitude of about 909 km, and an orbital inclination of about 99 degrees. The MOS-1 satellite, weighing about 750 kg, will be shot into this orbit with a two-stage N rocket type II and will be expected to fulfill its mission for 2 years. The radiometers to be borne aloft on this satellite will be the visible-near infrared radiometer, visible-thermal infrared radiometer, and microwave radiometer. All three radiometers can be used for simultaneous observations when the sun is striking, with combinations of two radiometers, or each radiometer by itself. When the visible-near infrared radiometer is operated alone, two systems of the same type of radiometers (see 2.1) can be used for simultaneous observations. Night observations (mealtime for the satellite) will be made for 15 minutes or less per cycle and 4 cycles or less per day with the visible-thermal infrared radiometer or the microwave radiometer.

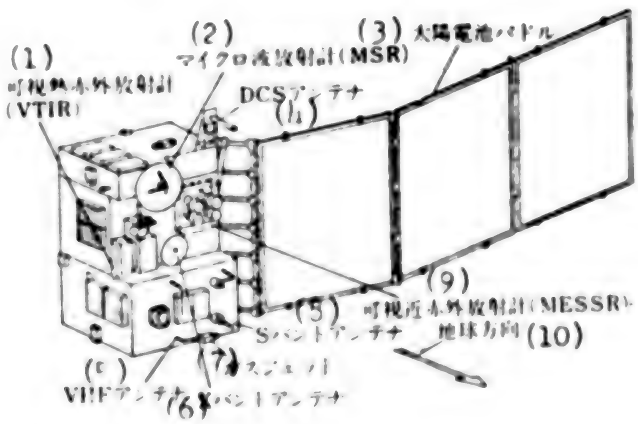

Figure 1. Diagram of Satellite

Key:

1. Visible-thermal infrared radiometer
2. Microwave radiometer
3. Solar battery paddle
4. DCS antenna
5. VHF antenna
6. X-band antenna
7. Gas jet
8. S-band antenna
9. Visible-near infrared radiometer
10. Direction of earth

The ground stations that will be engaged in the operation of this satellite will be mostly the tracking control stations of the Space Development Work Group. Acquisition of observation data from the skies over Japan will be assigned to the earth observation center at Hatojima. In order to comply with observational wishes on the part of foreign countries, the satellite will be provided with delay command capability, and operations beyond the region visible in Japan will also be possible. An external view of this satellite is shown in Fig 1, and the relationships between the satellite and ground stations are shown in Fig 2.

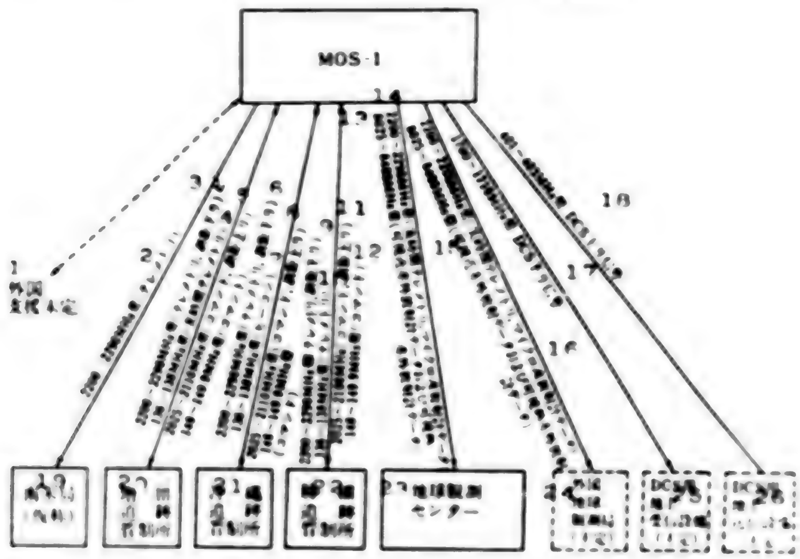

Figure 2. Relationships Between MOS-1 and Ground Stations

Key:

1. Unassigned foreign support
2. 2,200-2,290 MHz band (telemetry)
3. 2,200-2,290 MHz band (telemetry, downrange)
4. 136-138 MHz band (real-time telemetry)
5. 2,025-2,110 MHz band (command, uprange) 148-149.9 MHz band (command)
6. 2,200-2,290 MHz band (telemetry, downrange)
7. 136-138 MHz band (beacon)
8. 2,025-2,110 MHz band (command, uprange) 148-149 MHz band (command)
9. 2,200-2,290 MHz band (telemetry, downrange)
10. 136-138 MHz band (telemetry)
11. 2,025-2,110 MHz band (command, uprange)
12. 148-149.9 MHz band (command)
13. 8,025-8,400 MHz band (visible-near infrared radiometer and visible-thermal infrared radiometer data)
14. 2,200-2,290 MHz band (real-time telemetry, microwave radiometer data)
15. 8,025-8,400 MHz band (visible-near infrared and visible thermal infrared radiometer data)

[Key continued on following page]

16. 2,200-2,290 MHz band (real-time telemetry, microwave radiometer data)
17. 1,700-1,710 MHz band (DCS descending signal)
18. 401-403 MHz band DCS ascending signal
19. South American station (provisional designation)
20. Masuda tracking and control station
21. Okinawa tracking and control station
22. Katsuura tracking and control station
23. Earth Observation Center
24. Foreign earth observation center (not assigned)
25. Earth receiving facility for DCS use (unassigned)
26. Earth transmitting facility for DCS use (unassigned)

2. Outline of Marine Observation Satellite 1

The MOS-1 satellite will carry on board mission equipment such as equipment to observe land and sea areas and to process and transmit the data, and bus section equipment such as power supply, attitude control, and control and observation equipment for satellite observation. The block diagram for the overall satellite is shown in Fig 3.

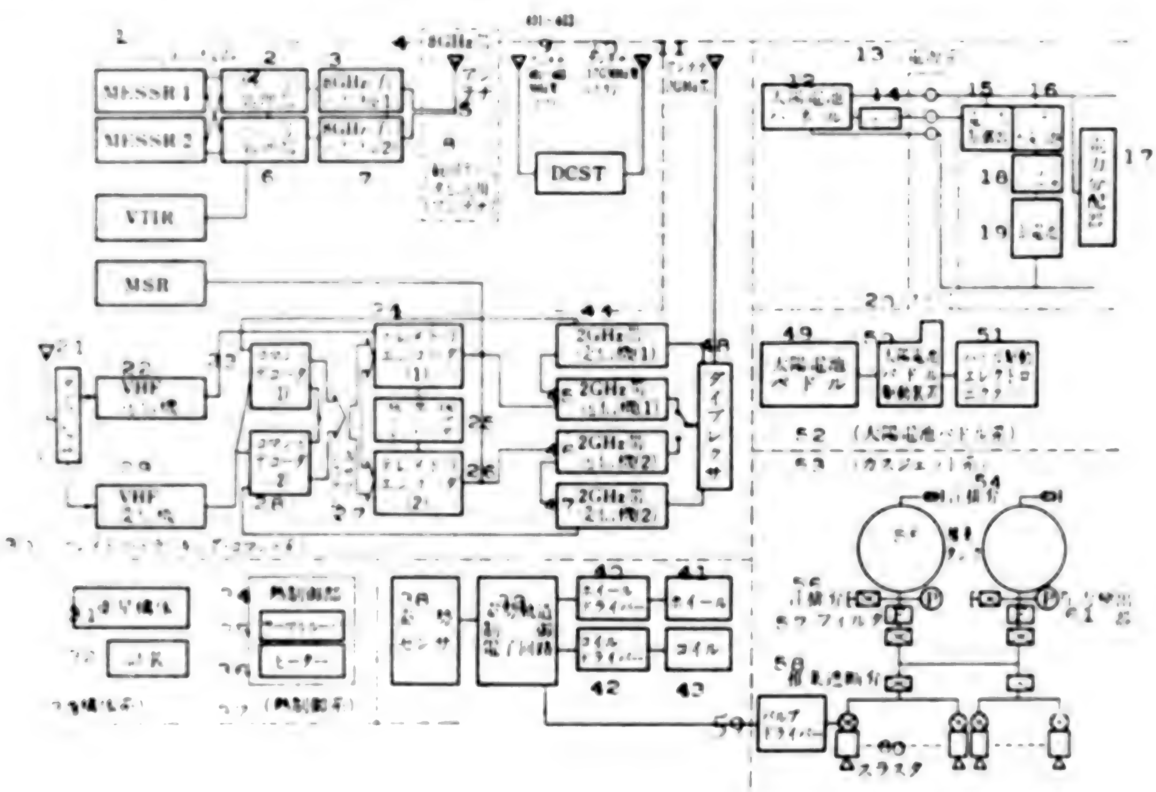

Figure 3. Block Diagram for the MOS-1 System

Key:

1. Mission equipment
2. Signal treatment section
3. 8 GHz(f_1) transmitter (1)
4. 8 GHz band
5. Antenna
6. Signal treatment section

[Key continued on following page]

7. 8 GHz (f_2) transmitter (2)
8. Observed data transmission antenna
9. Antenna 401-403 MHz band (ascending)
10. Antenna 1.7 GMHz band (descending)
11. Antenna 2 GHz band
12. Solar battery panel
13. Electric power system
14. Shunt
15. Power controller
16. Battery-charging circuit
17. Power distribution panel
18. Boost converter
19. Storage battery
20. Slip ring
21. Diplexer
22. VHF transmitter
23. Command decoder (1)
24. Telemetry encoder (1)
25. Narrowband-region tape recorder
26. Telemetry encoder (2)
27. Various subsystems
28. Command decoder (2)
29. VHF receiver
30. (Telemetry-tracking command system)
31. Satellite structure
32. Equipment
33. Structural system
34. Thermal control section
35. Thermal louver
36. Heater
37. Thermal control system
38. Attitude sensor
39. Attitude and orbit control electronic circuit
40. Wheel driver
41. Wheel
42. Coil driver
43. Coil
44. 2 GHz band receiver (1)
45. 2 GHz band transmitter (1)
46. 2 GHz band transmitter (2)
47. 2 GHz band receiver (2)
48. Diplexer
49. Solar battery paddle
50. Solar battery paddle drive device
51. Paddle drive electronics
52. (Solar battery paddle system)
53. (Gas jet system)
54. Intake-exhaust valve
55. Propellant tank
56. Intake-exhaust valve
57. Filter
58. Propellant shielding valve
59. Valve driver
60. Thruster
61. Pressure detector

2.1 Mission Equipment

The mission equipment for MOS-1 includes the three radiometer types of the visible-near infrared radiometer to make land and sea surface observations, the visible-thermal infrared radiometer, and the microwave radiometer; 8 GHz band high-speed data transmission section to transmit these observed data; and data collection relay to collect observation data taken up by buoys and similar units.

(1) Visible-near infrared radiometer (MESSR: multispectral electronic self-scanning radiometer)

The MESSR is a radiometer for making observations in the visible region and the near infrared region (4 channels). It features a 2,048 element charge-coupled device (CCD: charge-coupled device) as detecting element and uses an electronic scanning mode. The ground resolution is about 50 meters, and it has a narrow amplitude of about 100 km per radiometer, as a result of which two radiometer systems of the same wavelength region will be deployed with their central observation direction normal to the direction of travel of the satellite and with some overlapping in their scanning amplitudes, while the

observation regions can be switched around. The optical system will use a refracting lens mode, in which wavelength regions for two channels are received through a single lens system. The signals transmitted by CCD will undergo A/D conversion and synthesis at the data treatment section, and the data from the four channels and from the radiometer are supplied to the high-speed data transmitting section. A block diagram and the capabilities of this radiometer are shown in Fig 4 and Table 1.

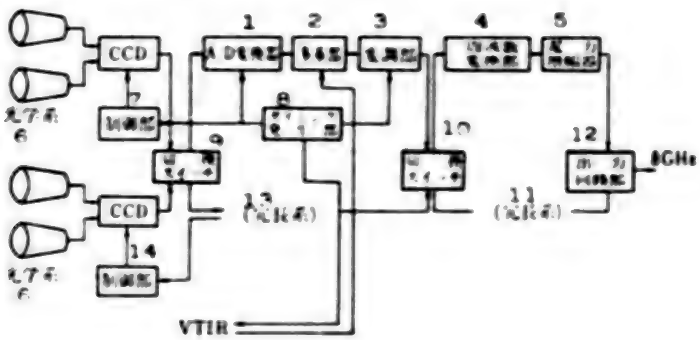

Figure 4. Block Diagram of the Visible-Near Infrared Radiometer

Key:

1. AD/converter
2. Overlapping section
3. Modulating section
4. Frequency varying section
5. Power amplification section
6. Optical system
7. Control section
8. Timing generation section
9. Cutover switch
10. Cutover switch
11. Redundant system
12. Output circuit section
13. Redundant system
14. Control section

Table 1. MESSR Capabilities

(1) 項目	(2) 性能
(3) 観測波長 (μm)	0.51~0.59 0.61~0.69 0.72~0.80 0.80~1.10
(4) 瞬時視野角 (μrad)	54.5±5
(5) 走査幅 (km)	100
(6) 走査方式	(7) 電子式
(8) 光学系	(9) ガウス・タイプ
(10) 検出器	(11) 2048素子CCD
S/N	39~15 dB
(12) 量子化レベル	(13) 64 (6ビット)
(14) 走査周期	7.6ms

[Key on following page]

Key:

1. Item
2. Capability
3. Observational wavelength (μm)
4. Instantaneous visible angle (μrad)
5. Scanning amplitude (km)
6. Scanning method
7. Electronic mode
8. Optical system
9. Gauss type
10. Detector
11. 2,048 element CCD
12. Quantized level
13. 64 (6 bit)
14. Scan period

(2) Visible-thermal infrared radiometer (VTR: Visible and Thermal Infrared Radiometer)

The VRIR is a radiometer with visible region (one channel) and thermal infrared region (three channels). It uses a silicon PIN diode as a detector for visible use and a mercury-cadmium-tellurium (HgCdTe) detector for the infrared channels. These detectors were developed for VTIR use. Each detector will incorporate two detector elements and will be provided with a redundant structure. Because of its operating characteristics, the infrared detector needs to be cooled to about 100 K; a radiation cooling unit with an opening into space will be provided. The resolution for ground observation will be about 1 km for the visible region and about 3 km for the infrared region, and a mechanical scanning mode will be used which rotates the scanning mirror about 7.3 RPS. The optical section will be of a Ritchey-Chretien type, and dichroic mirrors and filters will be used for light diffraction and wavelength control. The photographed signals will be amplified before undergoing A/D conversion, after which they will be sent to the visible-near infrared radiometer data treatment section through readout signals of the visible-near infrared radiometer and then transmitted to the ground. A block diagram of this radiometer is shown in Fig 5, and its capabilities are listed in Table 2.

Table 2. VTIR Capabilities

(1) [illegible]	(2) [illegible]	
	(3) [illegible]	(4) [illegible]
(5) [illegible] (μm)	0.5~0.7	6.0~7.0 10.5~11.5 11.5~12.5
(6) [illegible] (mrad)	1	3
(7) [illegible] (km)	[illegible]500	
(8) [illegible]	(9) [illegible]	
(10) [illegible]	[illegible] 3 s	
(11) [illegible]	(12) [illegible] Ritchey-Chretien	
(13) [illegible]	Si-PIN [illegible]	(14) HgCdTe
S/N	55 dB (ALb = 80%)	—
NEΔT		≤0.5K (AT 300K)
(15) [illegible]	256 (8 [illegible]) (16)	256 (8 [illegible]) (17)

[Key on following page]

Key:

1. Item	9. Objective plane mechanical scan
2. Capability	10. Scan period
3. Visible	11. Optical system
4. Infrared	12. Ritchey-Chretien type
5. Observational wavelength (μm)	13. Detector
	14. Si-PIN Diode
6. Instantaneous visible angle (mrad)	15. Quantized level
	16. 256 (8 bit)
7. Scanning amplitude (km)	17. 256 (8 bit)
8. Scanning method	

(3) Microwave radiometer (MSR: microwave scanning radiometer)

The MSR is a deck-type radiometer with 23 GHz and 31 GHz bands which will be used to measure radiation noise from the earth. It uses a newly developed receiver for broadband reception of the 500 MHz band, which can be apportioned to radioastronomy use centered on 23.8 and 31.4 GHz with temperature resolution 1-3 K. A conical scanning mode will be employed in which an offset Cassegrain for use with both bands rotates at about 18.7 RPM. In order to improve the precision of noise temperature determination, a comparative noise source whose temperature is accurately controlled and a standard noise source will be provided. At the same time, a skyhorn (Note 1) will be provided as a low temperature side standard noise source, and automatic corrections will be made to both the high temperature and low temperature sides per scan. There will be two measurement systems of an integration circuit (about 10 ms), with emphasis placed on ground surface resolution and an integration circuit (about 50 ms) with targeted temperature resolution of 1 K. The receiving mixer which controls the performance of this receiver and the broad band region low noise intermediate frequency amplifier were developed with the temperature characteristics in mind. In order to improve the stabilities in the measurement systems to temperature still further, an AGC circuit based on the skyhorn has been appended. A block diagram of this radiometer is shown in Fig 6, and the performance is listed in Table 3.

(4) Data transmission system

Because the 2-GHz bands used in the past could not cover the necessary regions for transmitting data greater than a total of 8 Mbit from the visible-near infrared and visible-thermal infrared radiometers, plans are under way to use a new 8-MHz band in MOS-1, and development of all solid state transmitter is under way with an anticipated final stage output of 4 W. The data transmission system is comprised of two frequency-redundant systems with differing central frequency, but when the two systems of the visible-near infrared radiometer are being observed simultaneously, the transmission system can operate in parallel. Furthermore, the microwave radiometer data will be transmitted through the 2-GHz band telemetry tracking command system of the satellite.

(Note 1) Skyhorn: Horn-type antenna which is installed so that it is normally directed toward the cold space to utilize the low temperature (about 4 K) of space as the standard low noise source for the low temperature side in brightness temperature measurements.

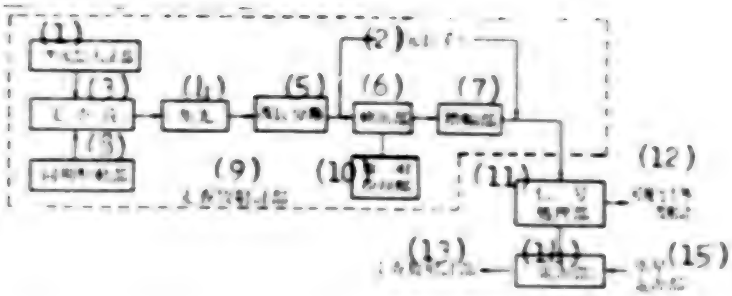

Figure 5. Block Diagram of Visible-Thermal Infrared Radiometer

Key:

1. Black body section/correction section
2. Redundant system
3. Scanning mirror
4. Condensed light
5. Wavelength separation
6. Detector section
7. Amplifier section
8. Period drive section
9. Scanning radiometer section
10. Radiative cooling section
11. Signal treatment section
12. Visible-near infrared radiometer
13. Scanning radiometer section
14. Power source section
15. Satellite power source section

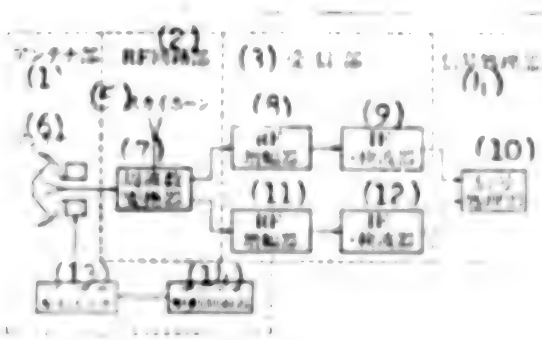

Figure 6. Block Diagram of the Microwave Radiometer

Key:

1. Antenna section
2. RF circuit section
3. Receiver
4. Signal treatment section
5. Skyhorn
6. Antenna
7. Frequency converter
8. RF amplifier
9. IF detector
10. Signal treatment unit
11. RF amplifier
12. IF detector
13. Antenna drive motor
14. Antenna drive control section

Table 3. MSR Capabilities

(1) [illegible]	(2) [illegible]	
	(3) 23 GHz [illegible]	(4) 31 GHz [illegible]
(5) [illegible] (GHz)	23.8±0.2	31.4±0.25
(6) アンテナビーム[illegible]	<2.0	<1.5
(7) [illegible] (ms)	(5) [illegible]	(8) [illegible]
(9) [illegible] (km)	317	
(10) [illegible]	(11) [illegible]	
(12) [illegible] (K)	30～330	
(13) アンテナ方式	(14) オフセットカセグレン方式	
(15) [illegible]タイプ	(16) ディッケタイプ	
(17) [illegible] (K)	<1 [illegible] (AT 300K)	
(18) [illegible] (s)	3.2	
(19) [illegible]レベル	(20) 1024 (10ビット)	

Key:

1. Item
2. Capability
3. 23-GHz band
4. 31-GHz band
5. Observational wavelength
6. Antenna beam width
7. Integration time (ms)
8. 10 and 47
9. Scan amplitude (km)
10. Scanning mode
11. Mechanical mode
12. Measured temperature range (K)
13. Antenna type
14. Offset Cassegrain type
15. Receiver type
16. Deck type
17. Temperature measurement precision (K)
18. Scanning period
19. Quantized level
20. 1,024 (10 bit)

(5) Data collection system transponder

The data collection transponder is a repeater that has been used in experiments to locate the position of buoys at sea, using Doppler frequencies, and to collect data from buoys located at sea. It receives 400-MHz-band signals from buoys which are converted into medium frequency and amplified after which the transmission waves are remodulated. In order to minimize the effects of changes in localized oscillation frequency of the repeater, a single localized oscillator is used in the repeater, and the receiving localized transmitting frequency [literal] and the transmission frequency are obtained from this single transmitter in the construction that is employed.

2.2 Bus Equipment for the Marine Observation Satellite 1

The bus equipment for MOS-1 will be comprised of the solar battery paddle system, which will supply the necessary power to the mission equipment and other bus sections, the power supply system, the attitude and orbit control system, the gas jet system, the telemetry and tracking command system for giving commands and conducting observations for the satellite operation, thermal control systems to control the temperature at various sections of the satellite, and the satellite structural system.

(1) Solar battery paddle system/power supply system

The supply of electric power when the sun is shining will be from the roughly 13,000 plates of 2 x 4 cm solar batteries pasted onto three panels. The two outermost panels of this array will be single-blade affairs positioned to be roughly perpendicular to the solar rays in order to optimize power-generating efficiency; they are expected to assure a supply of 530 W even after 2 years. There is a need for these solar batteries to always provide maximum generated power at all points of the orbit by controlling the paddles so that their surfaces are always facing the direction of the solar rays. Since this orbit will be synchronous with the sun, the angle between the orbit and the solar rays will be constant, and by adjusting the paddles in a fixed manner in inertial space so that maximum output is obtained, a constant power supply will be assured. This can be accomplished by rotating the satellite about the paddle axis adjusted to the rotation of the satellite about the earth.

The power generated by the solar battery paddles will be stabilized to about 29 V fixed voltage by the power controller of the power supply system and will be supplied to the various equipment aboard the satellite. Power will be supplied during the satellite's mealtime through a set of three 15 AH (total of 45 AH) storage batteries through a boost converter.

(2) Attitude and orbital control system/gas jet system

Attitude control of the MOS-1 will be an important function which will control the degree of attainment of the mission of the observational satellite. The MOS-1 in steady state condition will employ a bias-momentum-type triaxial attitude control mode, in which two momentum wheels will be deployed in a V-shaped affair, and wheel unloading will be through the use of magnetic trucker [phonetic] to achieve soft attitude control.

Liquid jets using hydrazine as fuel will be used to attain attitude at the initial stage of launch, to make any readjustments that are necessary, and to make orbital corrections in order to achieve an orbit that is synchronous with the sun.

Rate gyro, solar sensor, and static type earth sensor will be carried aboard the satellite as sensors for attitude control.

A completely redundant structural system will be employed for the control systems, in view of their importance, together with a contingency maneuver in

the event something happens and the attitude is lost (Note 2)--thereby providing a means to recapture the attitude.

(3) Telemetry, Tracking, and Command System (TT and C System)

The TT and C system is comprised of the No 1 transmitter-receiver system of the VHF band, the No 2 transmitter-receiver system of the S band (redundant system), and the completely redundant telemetry, encoder, command, decoder, and telemetry use tape recorders. The VHF band will be used at the initial stage of launching and during emergencies and will receive command signals and telemetry signals (either real-time telemetry signals or telemetry data from the tape recorder). The S band will be used during operation in orbit and will be used for relaying measurement signals on the R and RR (range and range rate) by the USB mode (unified S band mode) for orbital determination, receiving command signals, real-time telemetry, telemetering in real time, and for transmitting recorded telemetry data from tape recorders. In addition, it will supply baseband data from telemetry to the signal treatment section of the visible-near infrared and visible-thermal infrared spectrometers for image processing.

(4) Thermal Control System/Structural System

Since MOS-1 will be a solar-synchronous satellite, the thermal conditions aboard the satellite will be comparatively stable, but it will carry radiometers that are very sensitive to external radiation, necessitating very strict thermal control over the entire satellite. As a result, a construction will be adopted in which the outer surface of the structure will be covered by a thermal blanket to suppress thermal input from solar radiation and earth radiation. Those areas not covered by the thermal blanket and certain instruments will be covered with thermal coating.

As a result, the satellite will be greatly affected by heat generation from the internal instruments, and internal temperature adjustments will be made through the use of thermal louvers and improved thermal conduction to disperse this heat, while heaters attached to the rotary sections will come into play when the satellite becomes cooled excessively because of lowered capacities of the cooling systems.

The construction of the satellite body will be a honeycomb sandwich panel box affair with emphasis on weight reduction, in which the bus-related equipment will be loaded in the lower section while the mission equipment will be placed over it. At the same time, the large movable solar battery panels and the fuel (tank), whose residual weight will vary, will be installed at the middle panel of the satellite for attitude control considerations in order to minimize shifts in the center of gravity in the construction to be adopted.

(Note 2) Contingency maneuver: When there is some malfunction of the satellite's attitude control system, with the result that the attitude deviates from its normal state, this malfunction will be detected and the attitude will be restored to a safe direction in order to prevent any mortal damage to other equipment on the satellite.

The mission equipment and transmission antenna will be the main equipment deployed to the plane facing the earth, while the solar battery paddles will be installed at the side toward the sun, and there will be thermal louvers and registers installed in the space on the opposite side. The height of the main body of the satellite will be about 2.4 meters, its width will be about 1.6 meters, and its depth will be about 1.5 meters (excluding projecting sections).

Among the important subsystems, Mitsubishi Electric is in charge of the attitude control system, Toshiba Corporation is in charge of the solar battery paddle system, and Ishikawajima-Harima is in charge of the gas jet system, while Nippon Electric will take all these subsystems and put the satellite system together. In this manner, the important domestic satellite manufacturers are participating in this project and handling their own particular specialty areas, giving this problem the merit of concentrating existing technology. On the other hand, interfacing is complex, and this is bringing up difficulties.

The present situation is that the basic plan inspection of the overall satellite system was completed in July 1981, and the detailed design phase has been entered. The basic plans of the principal mission equipment of the visible-near infrared radiometer (the responsibility of Nippon Electric), the visible-thermal infrared radiometer (Fujitsu), and microwave radiometer (Mitsubishi Electric) were completed prior to the main body plans, and the principal functional tests using engineering models are almost complete. The detailed design inspection of the entire system is planned for completion next summer, when the design will be accepted. Next, the production/test phase will be completed, and subsequent developments will be pushed to enable the realization of a domestically produced earth observation satellite with launching targeted for 1986.

Postscript: From Science to Fantasy

According to an ancient poem, "When one looks at the moon, he senses extreme sadness even though he is not at the autumn of his life." This moon, along with the evening star and morning star, has been the object of sentimentality as well as romanticism to people of yore. On the other hand, direct observations by manmade search through space explorations and ground-based observations through the use of radiotelescopes and radar during the past 20 years or so of space explorations have revealed the true nature of these heavenly bodies, and the stars and moon no longer have the strong romantic appeal to man.

In another direction, advances in modern science led by astronomical and physical studies through the efforts of scientists over the past several hundred years from Galileo to Einstein have resulted in a shift in man's outlook from a philosophical view to a human view of life.

The four satellites about Jupiter which Galileo barely discovered with his handmade telescope have been clearly photographed recently by Voyagers 1 and 2, and man has come to the stage where he is no longer amazed by these photographs.

NASA's Galileo project, which proposed further exploration of Jupiter starting with the four satellites and then into the interior of Jupiter itself, is said to have been terminated by Reagan's budgetary cuts, according to recent reports; however, I am pleased to hear that this project is expected to be revived. At the same time, the VOIR plan, which proposes radar observation of Venus from above the clouds, hopefully may be realized by one means or other.

Even in Japan, the PLANET-A project introduced in this journal for observing Halley's Comet will be a project which should come into fruition in the course of another 3 years, and plans to construct a 64-meter-diameter large antenna for communicating with this satellite were initiated by the same Space Science Laboratory.

There are also hints of sending an Orbiter around the moon to make observations and of launching artificial satellites beyond the sun in order to verify Einstein's relativity theory.

Assuming from all this that the present age is an age from fantasy to science, it may also be said that there is simultaneously the start of an age from science to fantasy. The "Hakucho" observational data, which are the products of epochmaking success in the area of x-ray astronomy, have been instrumental in explaining the activity of neutron stars, and they even hint at the existence of black holes.

Present-day science is applying its scalpel to objects at hand in order to cut away the veil of mystery, but it is also giving birth to other separate mysteries such as black holes and other space developments which it cannot explain. We seem to have entered an age of science to fantasy in which we are viewing things in a new romantic dream.

(Toshimitsu Nishimura, Space Science Laboratory)

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